Microwave Processing of Oil Contaminated Drill Cuttings

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October 2009

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- What are the drilling wastes?
- How do we deal with these wastes?
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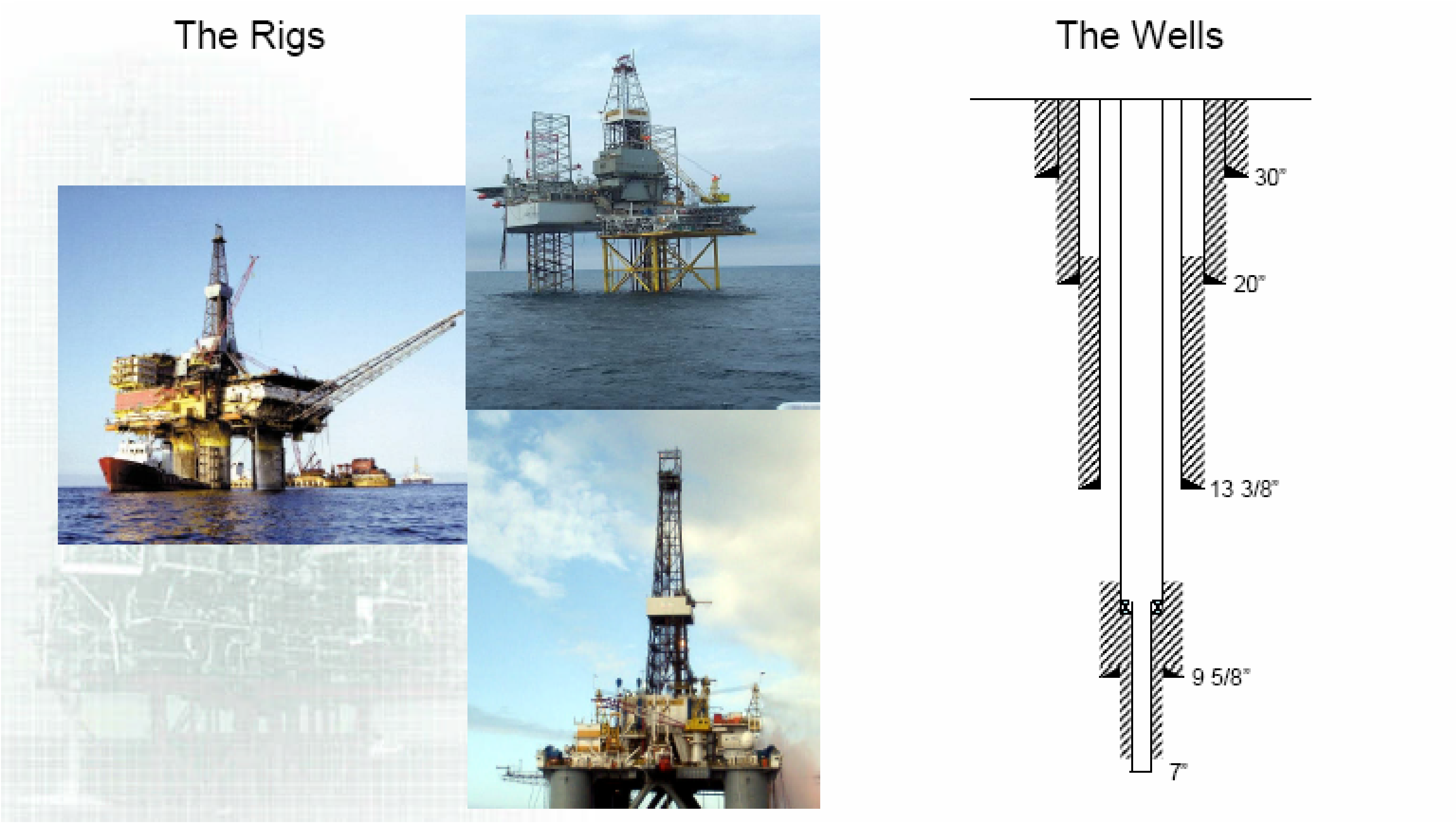
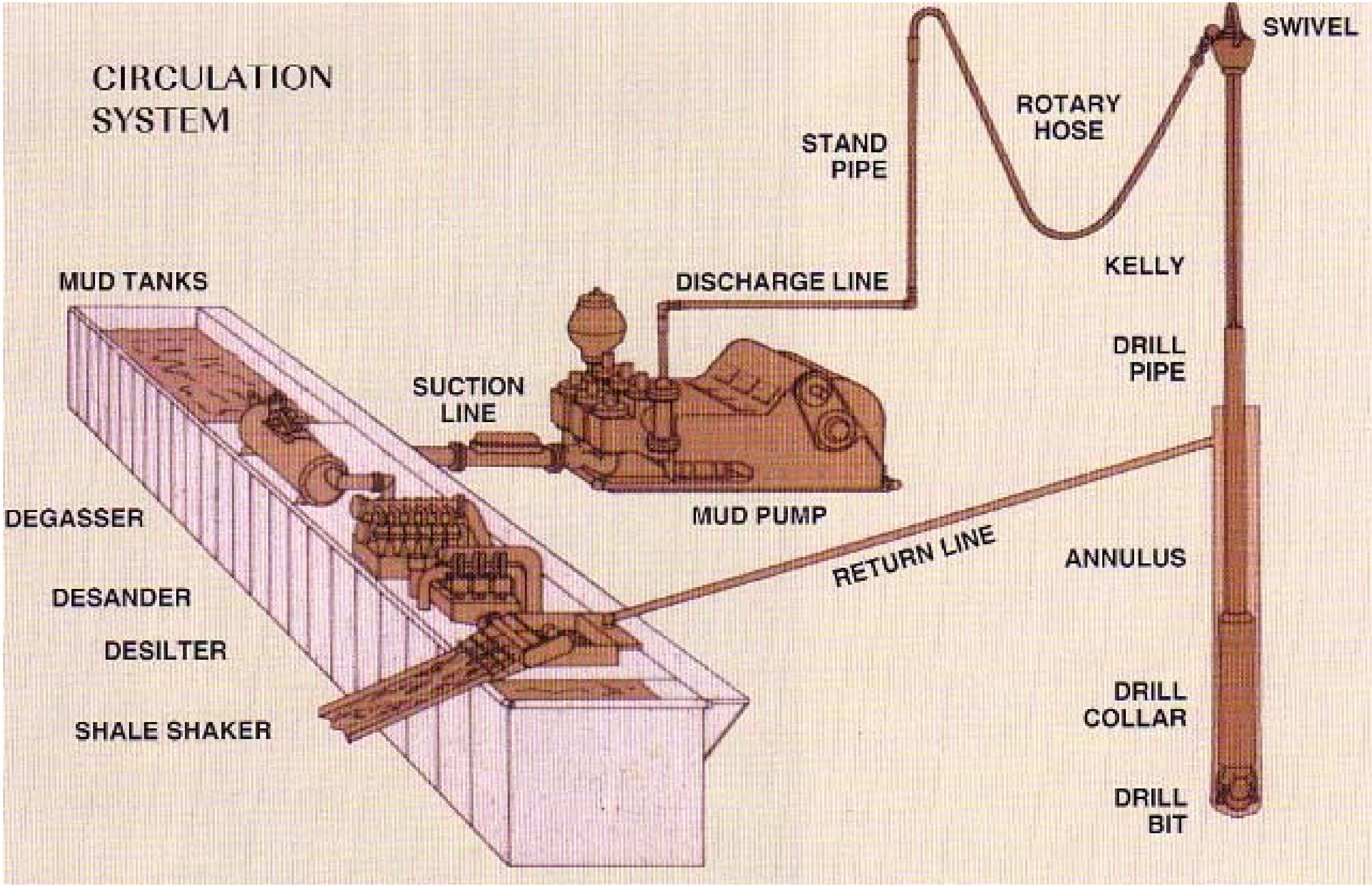
How are drilling wastes generated?

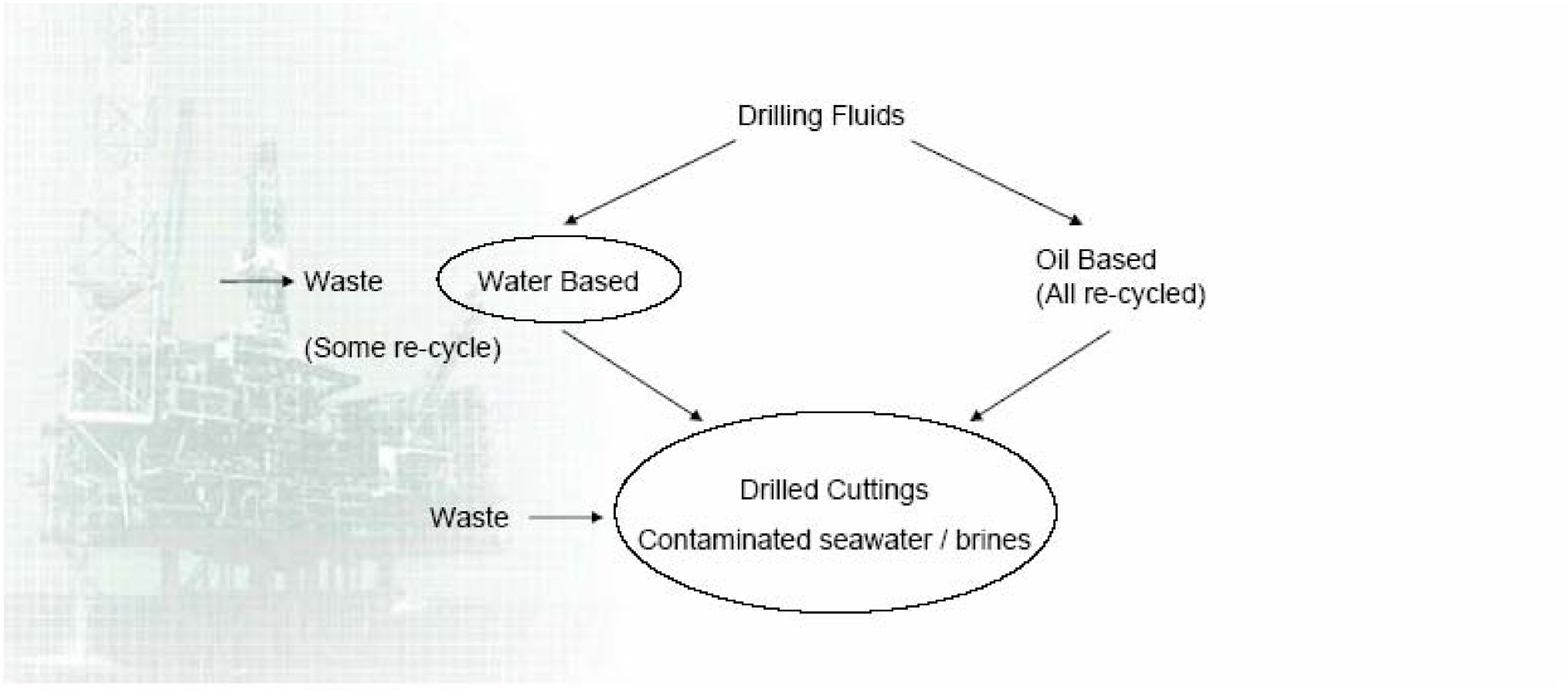


Circulating system and solids control



The role of drilling fluids in drilling waste

- Drilling fluids have complex chemistry. They are designed on a well to well basis. They become a waste and create waste.



Scale of the waste

- There is no such thing as a typical waste.
- Drilled cuttings vary in nature (consistency) and rate of production.

This makes processing complex

Oil based contaminated cuttings	200 – 1,000 mt / well

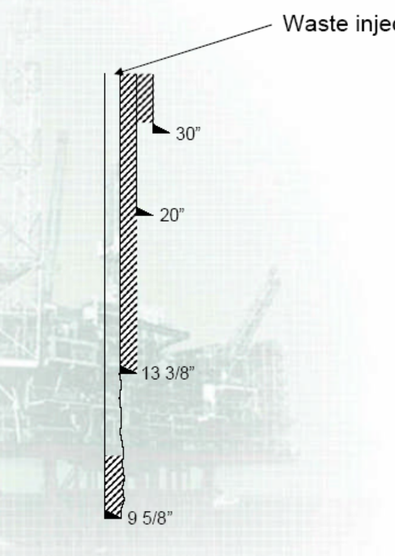
Dealing with oil based waste streams in the North Sea

The History:

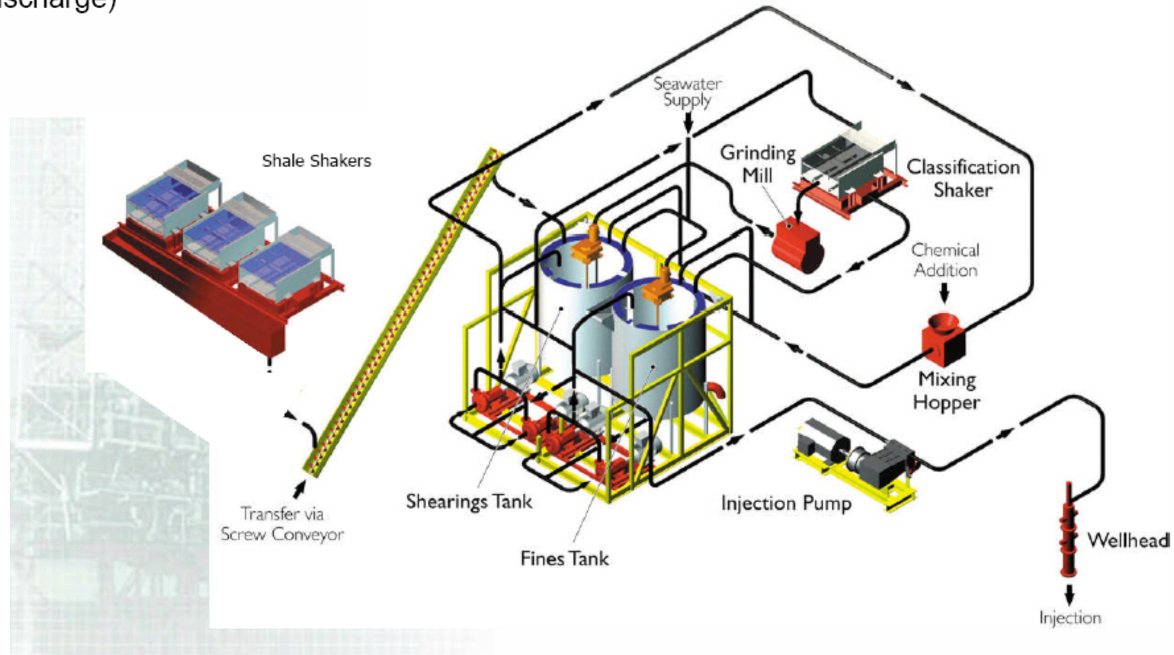
- Diesel based fluids introduced in late 70’s.
- Replaced by mineral oils in 80’s.
- Replaced by synthetic bases in mid 90’s.
- All oil and synthetic based fluids prohibited for discharge from 2000 (< 1% allowed).
- Industry now utilises refined mineral oil as the base for the fluid.

Cuttings re-injection through surface wellheads

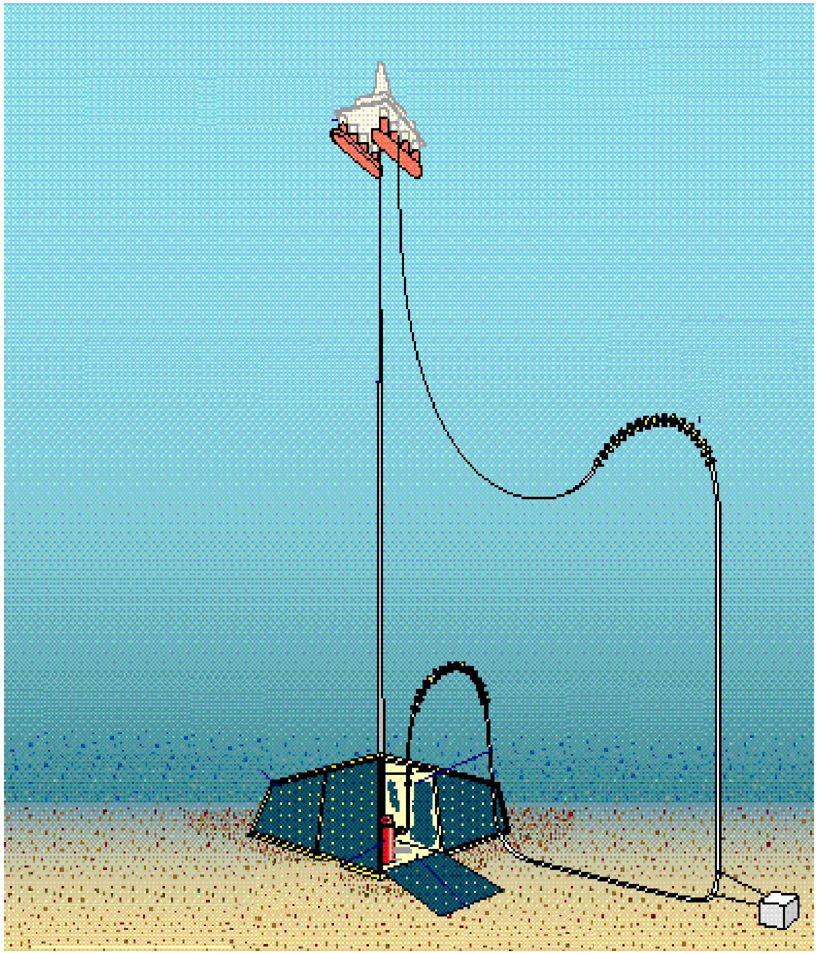
Platforms – all BP Platforms equipped with cuttings reinjection systems



- Typically around 1,000m ss.
- Wells may take several hundred thousand bbls of slurry.
- Annular injection used.
- Now all drilling wastes injected. (Moving to zero discharge)



Cuttings Re-injection through subsea wellheads

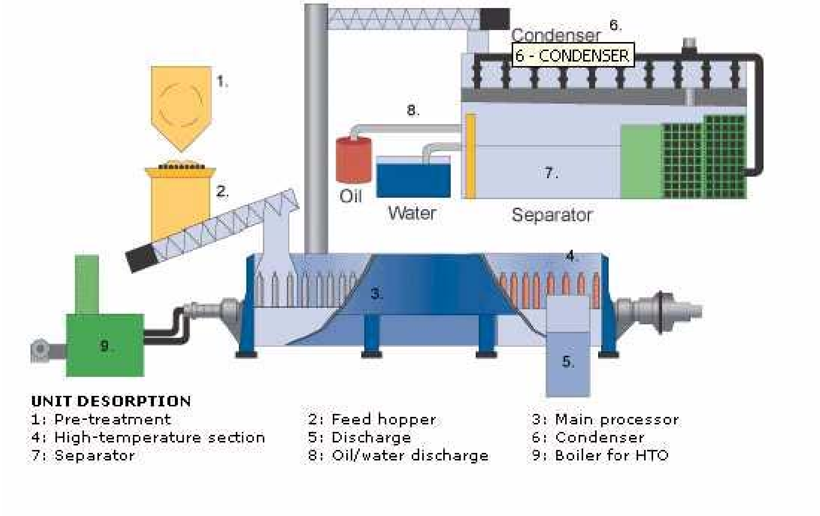


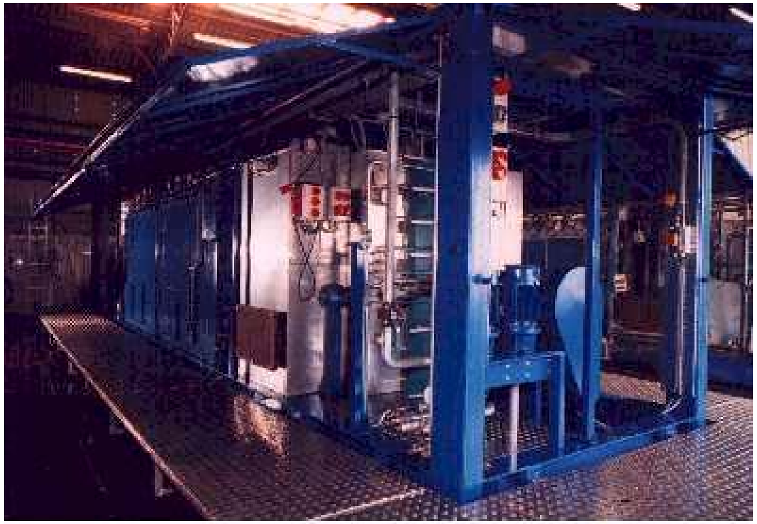
- Subsea injection is possible.
- BP ran first offshore trial in 1991 as a R&D project (Drilquip & FMC).
- 1998 - first global commercial use of sub-sea re-injection with Statoil using Coflexip Stena Offshore system.
- 300 m water depth.
- 20,000 m^3 injected
- However, needs 15 – 20 wells to be economic.

Onshore Processing

- Majority of cuttings now brought to shore for thermal processing prior to land fill (50,000 – 70,000 mt / annum)





Onshore treatment and disposal

- Despite many field trials, thermal treatment followed by land fill is still used.

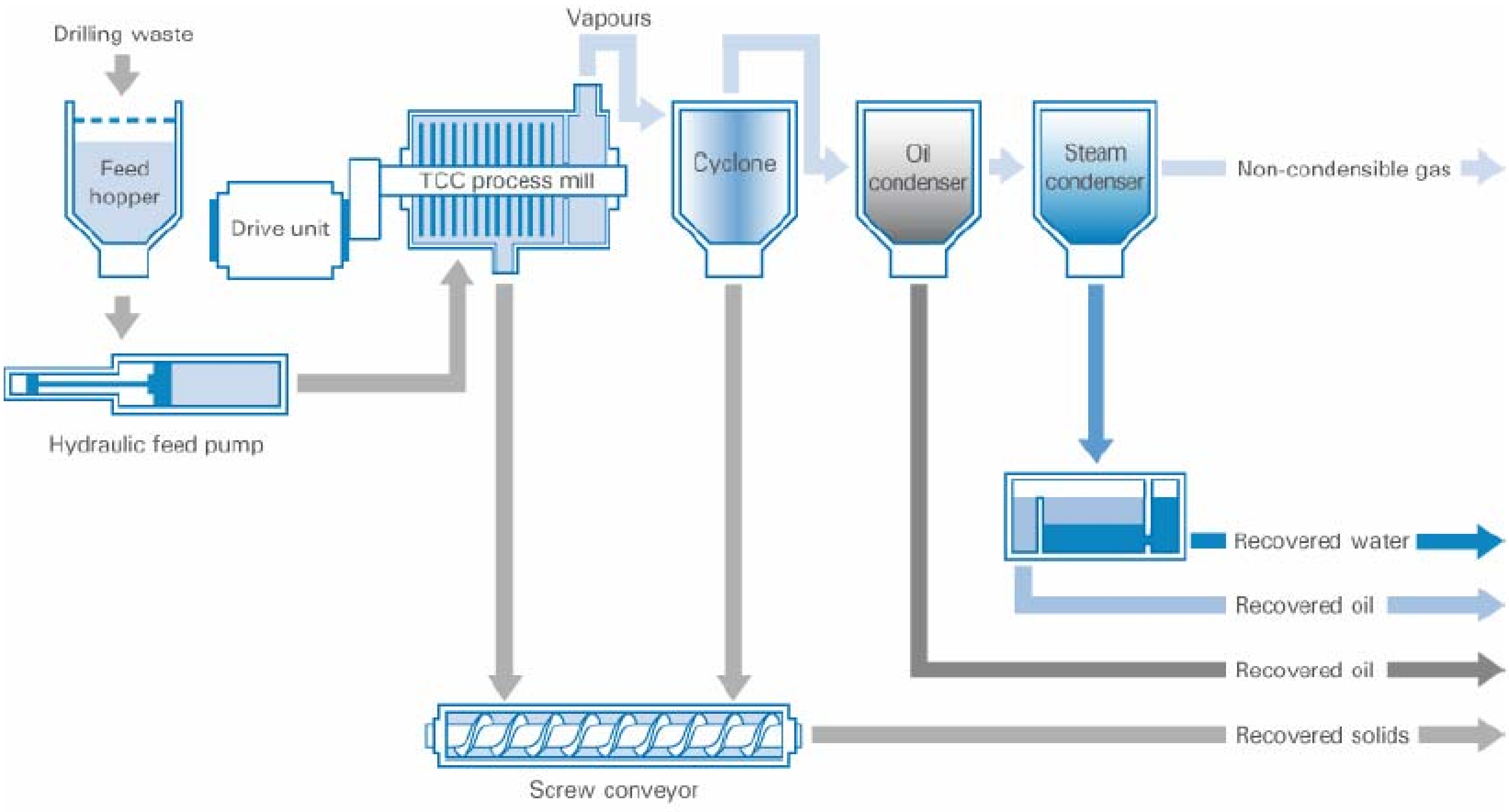
<u>Tried</u>

- Coal fired power station (fuel)
- Bioremediation
- Cold asphalt encapsulation

Commercial and logistics wrong.

Offshore processing of oily drill cuttings

- Thermtec – Thermomechanical Cuttings Cleaner (TCC)

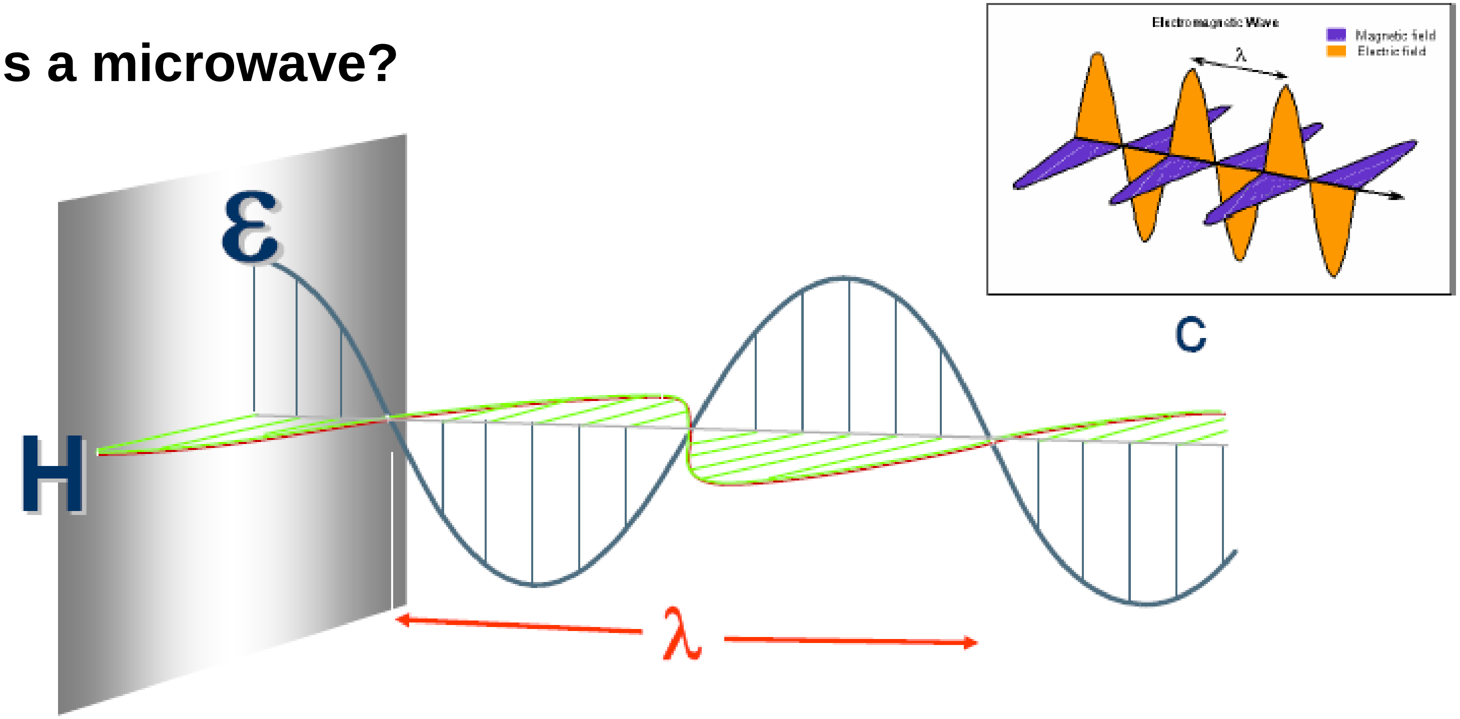


Offshore processing of oily drill cuttings

- TCC RotoMill on board the Global Santa Fe Artic IV in the UK sector of the North Sea

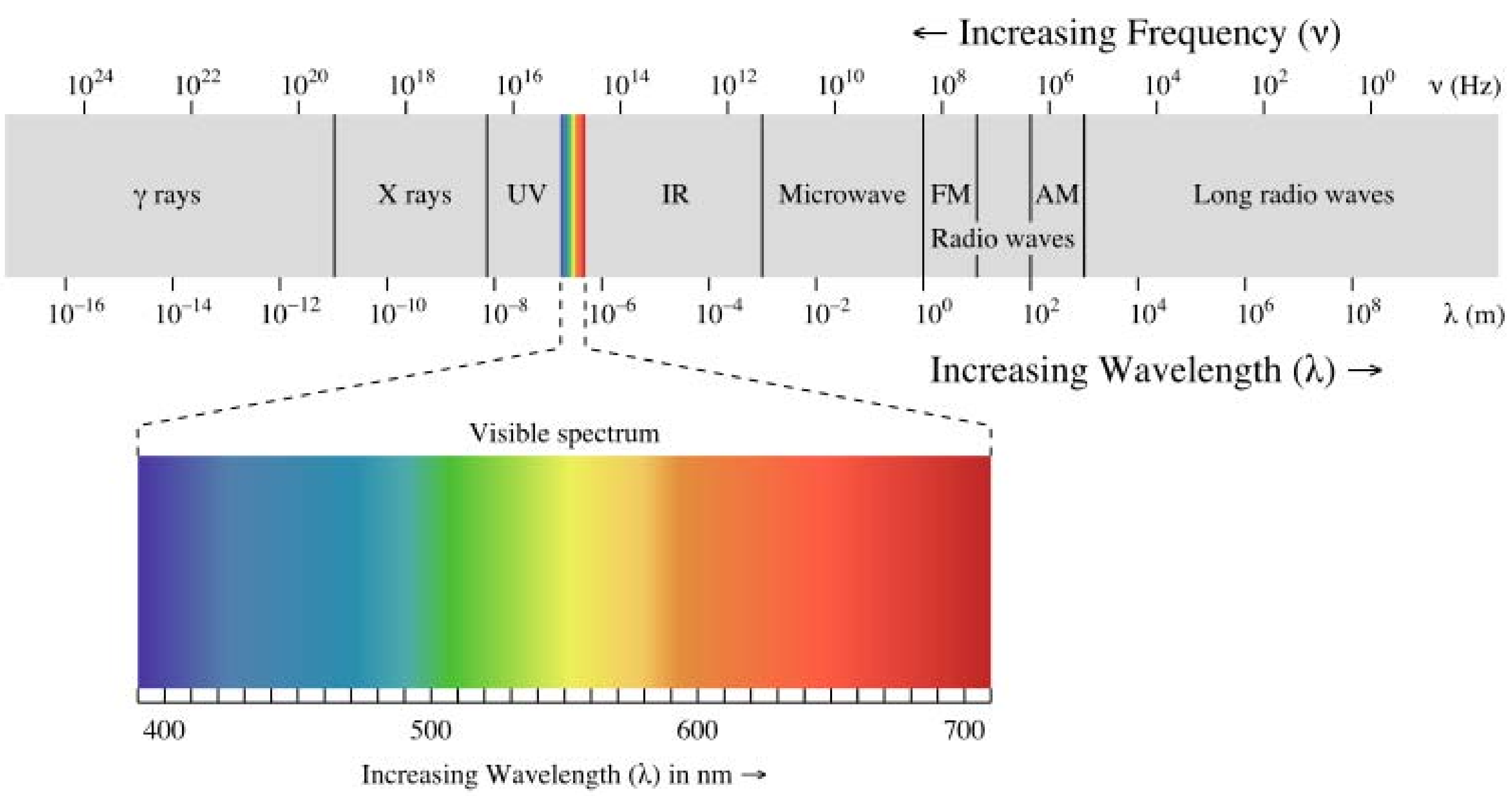
- Processed drill cuttings for 12-1/4” and 8-1/2” hole sections
- Operational performance - **12-1/4” hole section ONLY**:
  - Total cuttings generated: 378 MT
    - equiv. 75 skips of 5MT filling capacity
  - Total cutting slurry processed: 517MT (include added mud)
  - Total **recovery** / discharged:
    - **Base oil: 402bbl**
    - Water: 59.77m^3 (with total of 2.10kg HC, i.e. 0.004%HC)
    - Solid/Dust: 431.88 MT (with total of 97.20kg HC, i.e. 0.023%HC)
  - Process rate: 4.5MT/h (average)

What is a microwave?



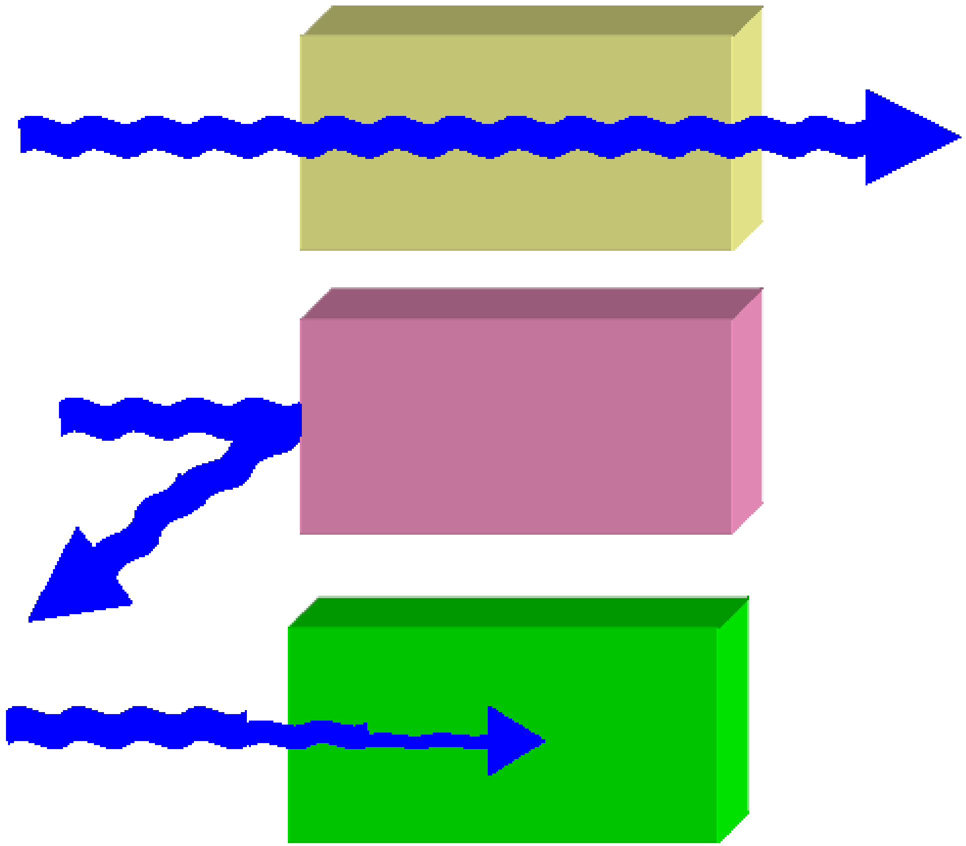
ε = electric field
H = magnetic field
λ = wavelength (12.2 cm for 2450 MHz)
c = speed of light (300,000 km/s)

What is a microwave?



Microwave heating at 3 key frequencies only

Material interaction

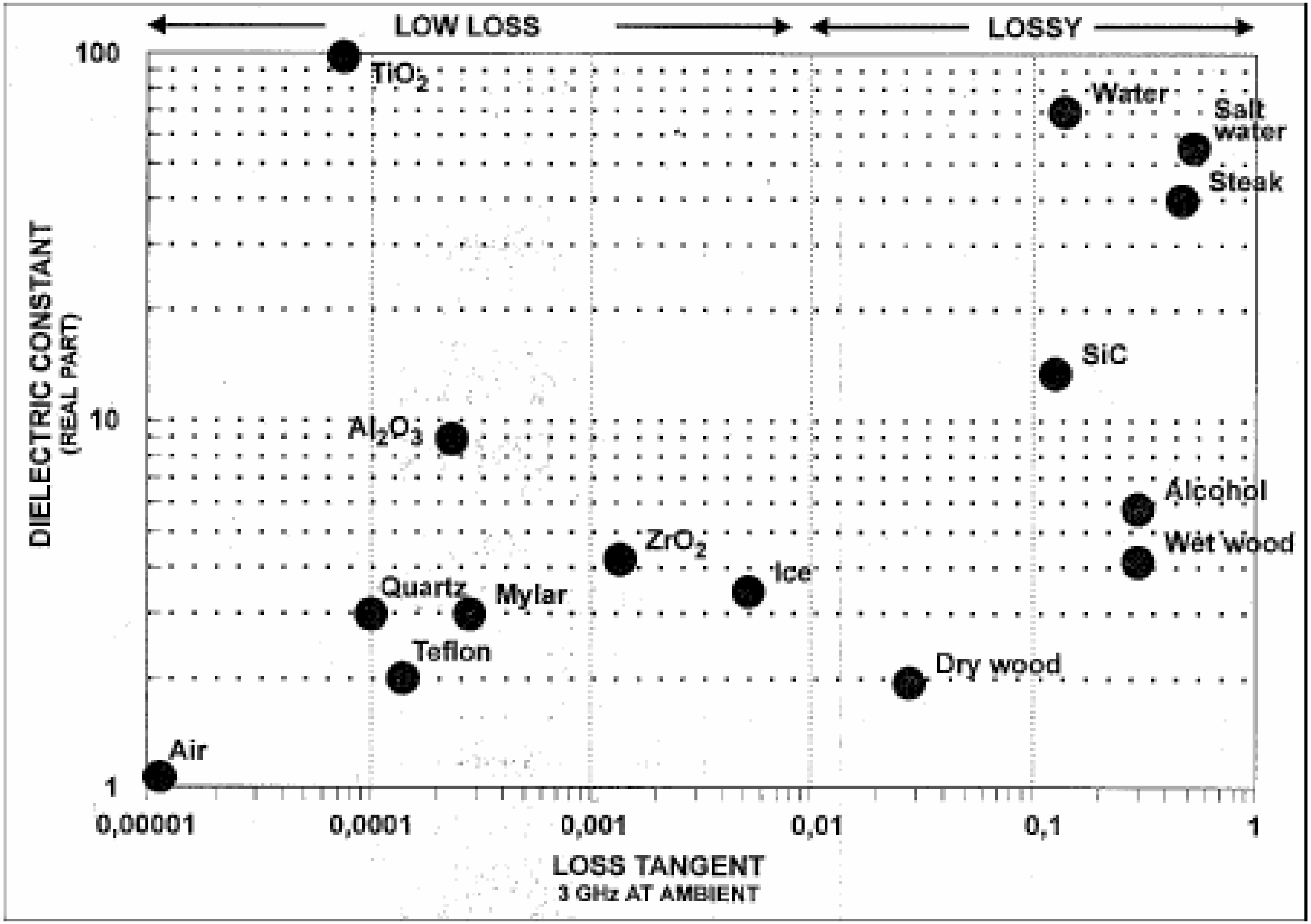


- Transparent
- Reflect
- Absorb

Dielectric properties

- Describes the interaction between the electric field and a material.
  - Determine how well a material will heat in a microwave field
- Vary with temperature, frequency, density, moisture content
  - Specialised techniques to measure
- They consist of 2 parts
  - Dielectric Constant (ability to store energy)
  - Loss Factor (ability to convert stored energy to heat)
- Loss Tangent = Loss Factor / Dielectric Contant
  - Good measure of microwave heating ability

Common materials

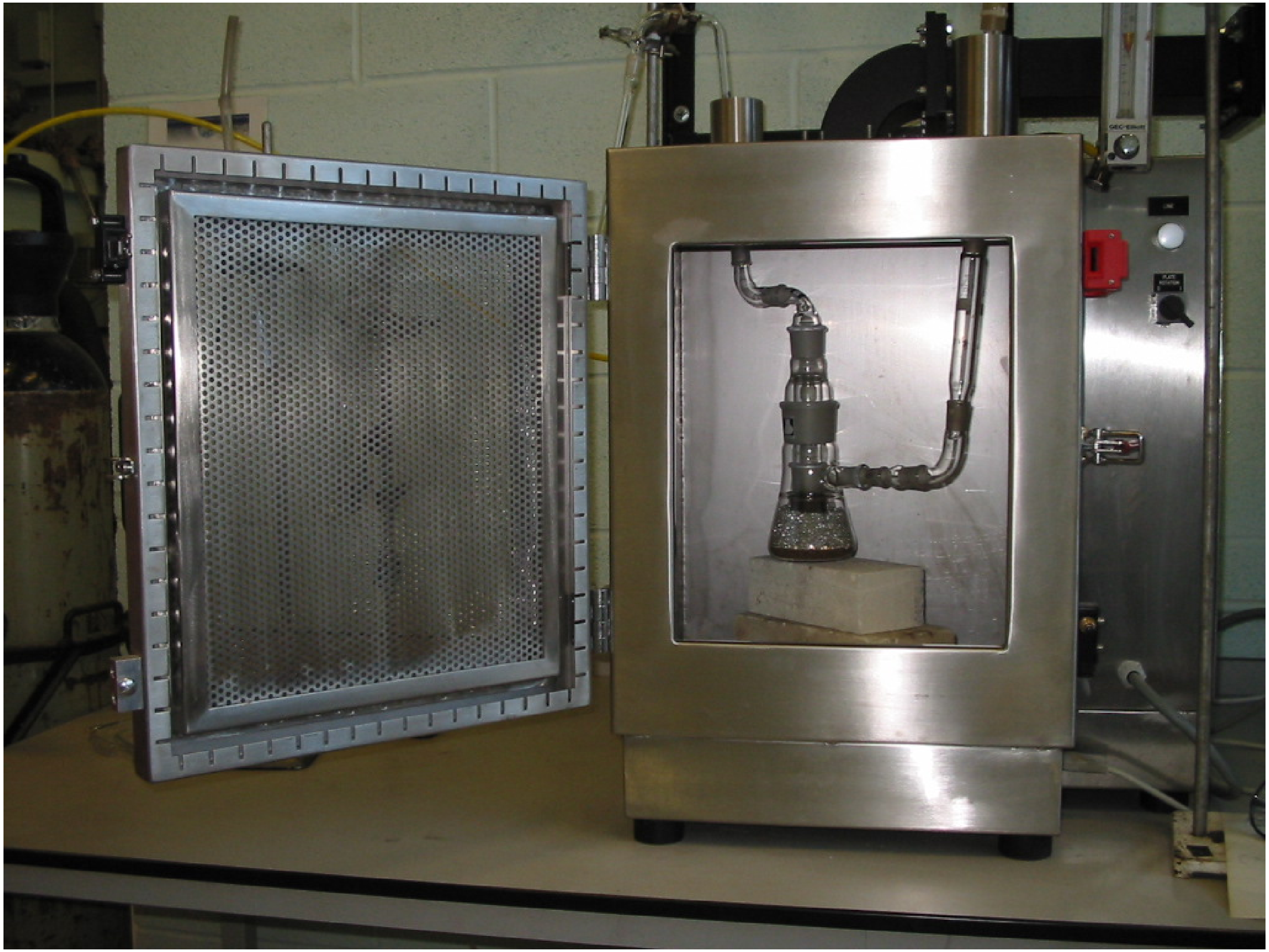


Microwave treatment mechanisms

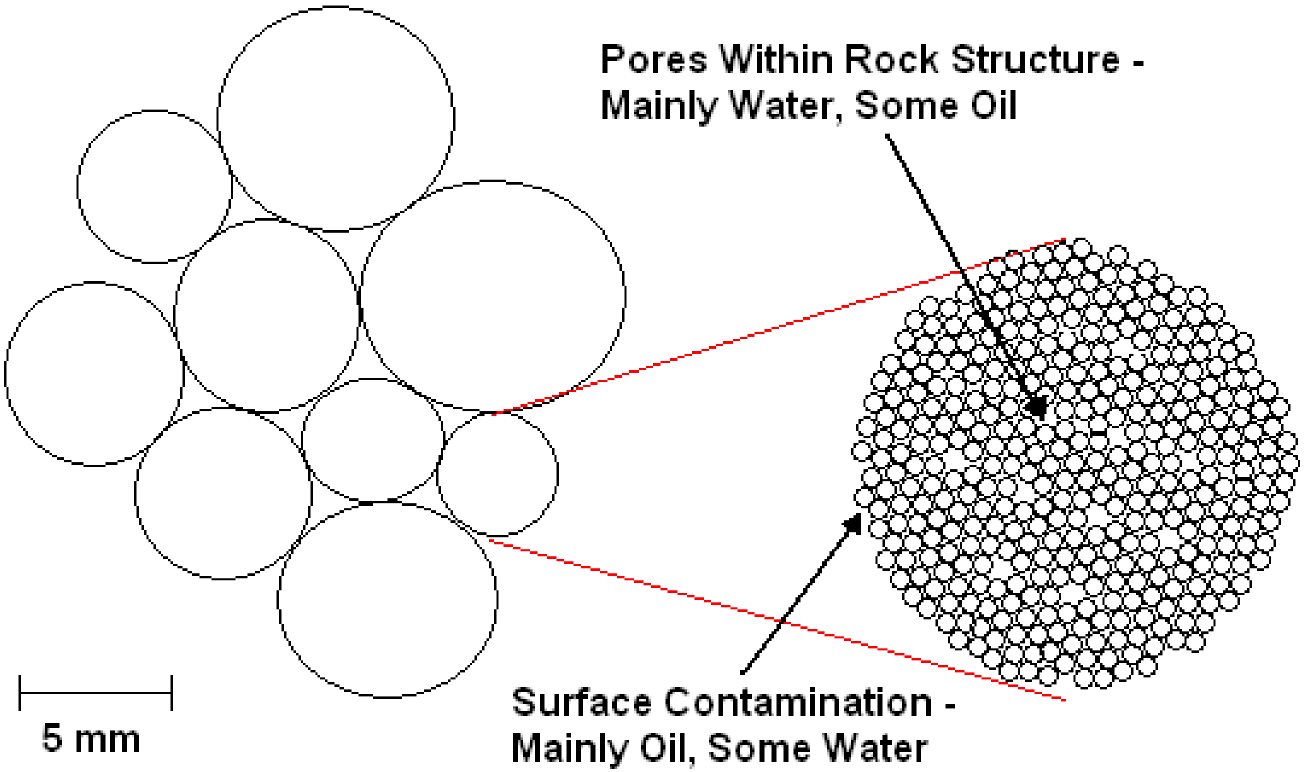
Studies of dielectric properties showed that water is the only phase that can be directly heated by microwaves:

Material	Dielectric Constant (ε') at 25°C	Dielectric Loss Factor (ε'') at 25°C
Oil	2	0.002
Feldspar	2.6	0.02
Quartz	3.8	0.001
Mica	1.6	0.005
Water	77	13

Microwave Processing of Oil Contaminated Drill Cuttings



Oil removal mechanisms - Entrainment



- Entrainment of oil with escaping pore-steam is the target mechanism – requires a high heating rate
- Only water is heated
- Oil is removed as liquid droplets
- Bulk temperatures do not exceed 100°C

Oil Removal Mechanisms

The fundamental effects were further decoupled into four specific mechanisms, all of which arise from heating water:

1. Entrainment of oil in steam created from interstitial water
2. Steam Distillation (boiling point depression)
3. Conventional drying - stripping / absorption in sweep gas
4. Thermal desorption of oil via heat transfer from superheated water

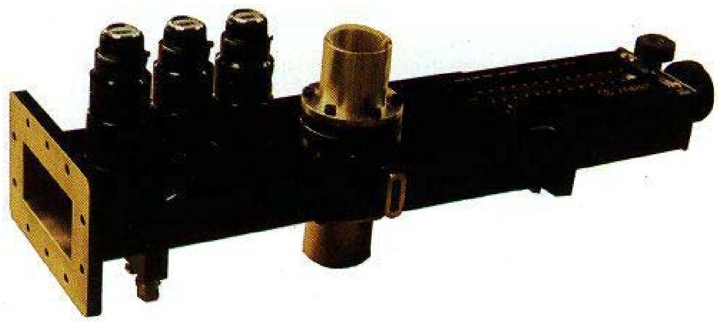
Advantages of microwave treatment of oil contaminated drill cuttings

- Selective Heating
  - High efficiency - energy is not wasted heating the entire process material
- Volumetric Heating
  - Granular materials such as drill cuttings have very poor heat transfer properties
  - Microwave heating can be complete within seconds
  - Low residence time requirement which leads to equipment with a small footprint
- Electrically Operated
  - Low utility demand
  - High conversion efficiency from electricity to MW (~90%)

Microwave heating systems

- Few processes use off the shelf applicator designs
  - Different material properties
  - Different process requirements
- Geometry critically determines performance
- Different types but:
  - Need to consider mechanism (time, power, power density etc)

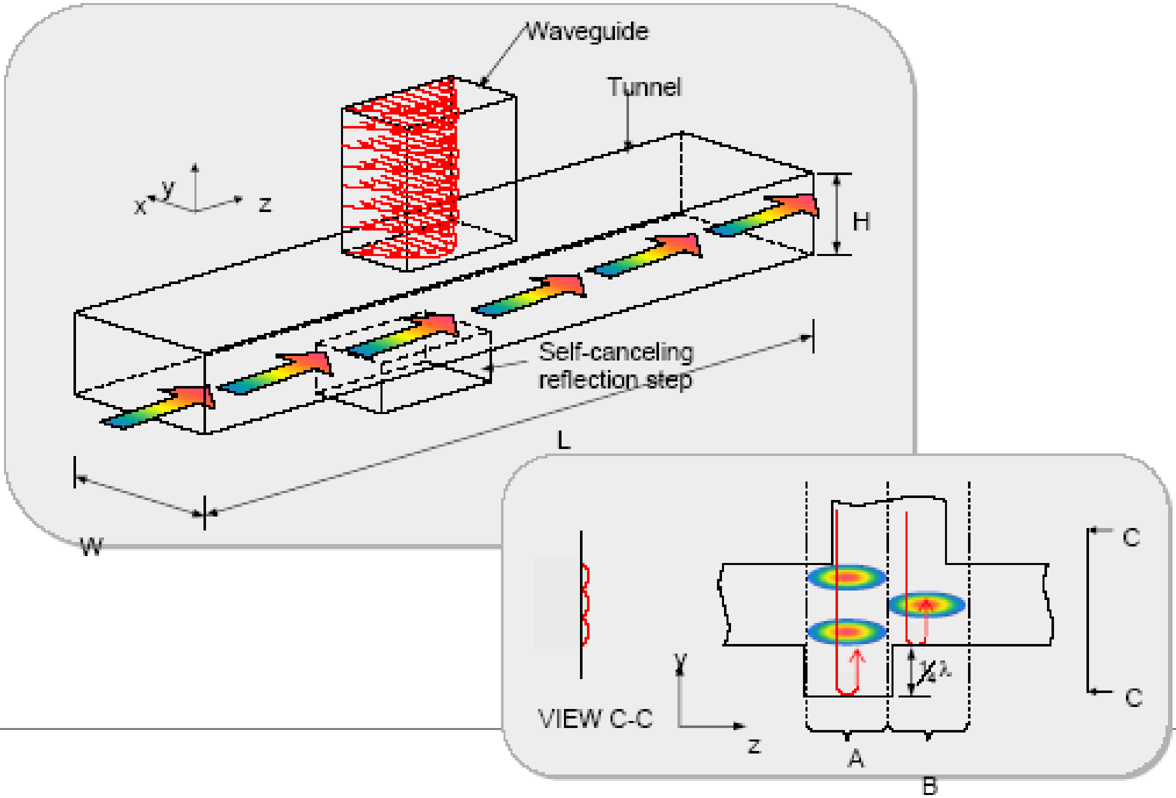
Multi-mode cavity



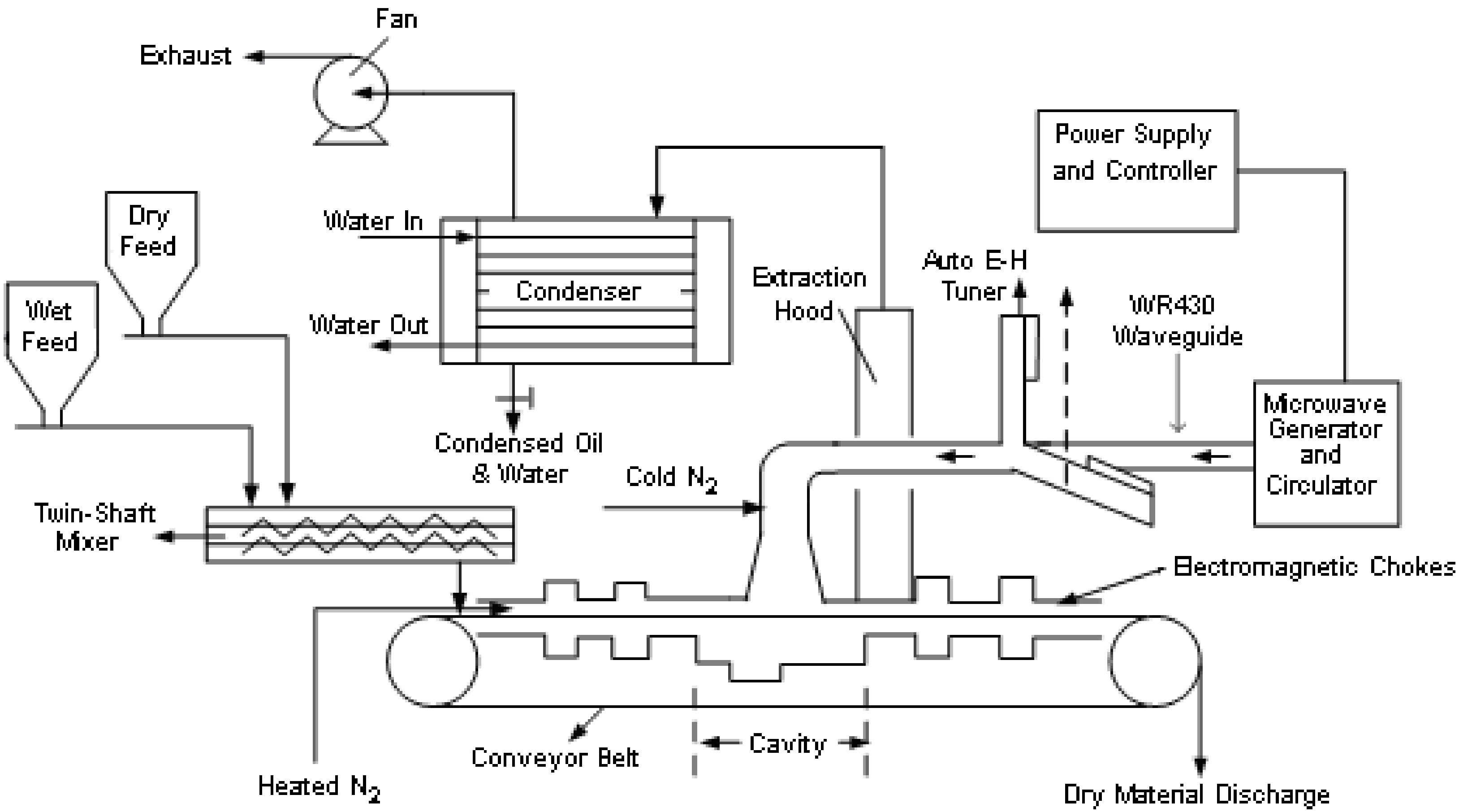
Single-mode cavity

Scale-up concept

- The chosen concept for development was a ‘tunnel applicator’

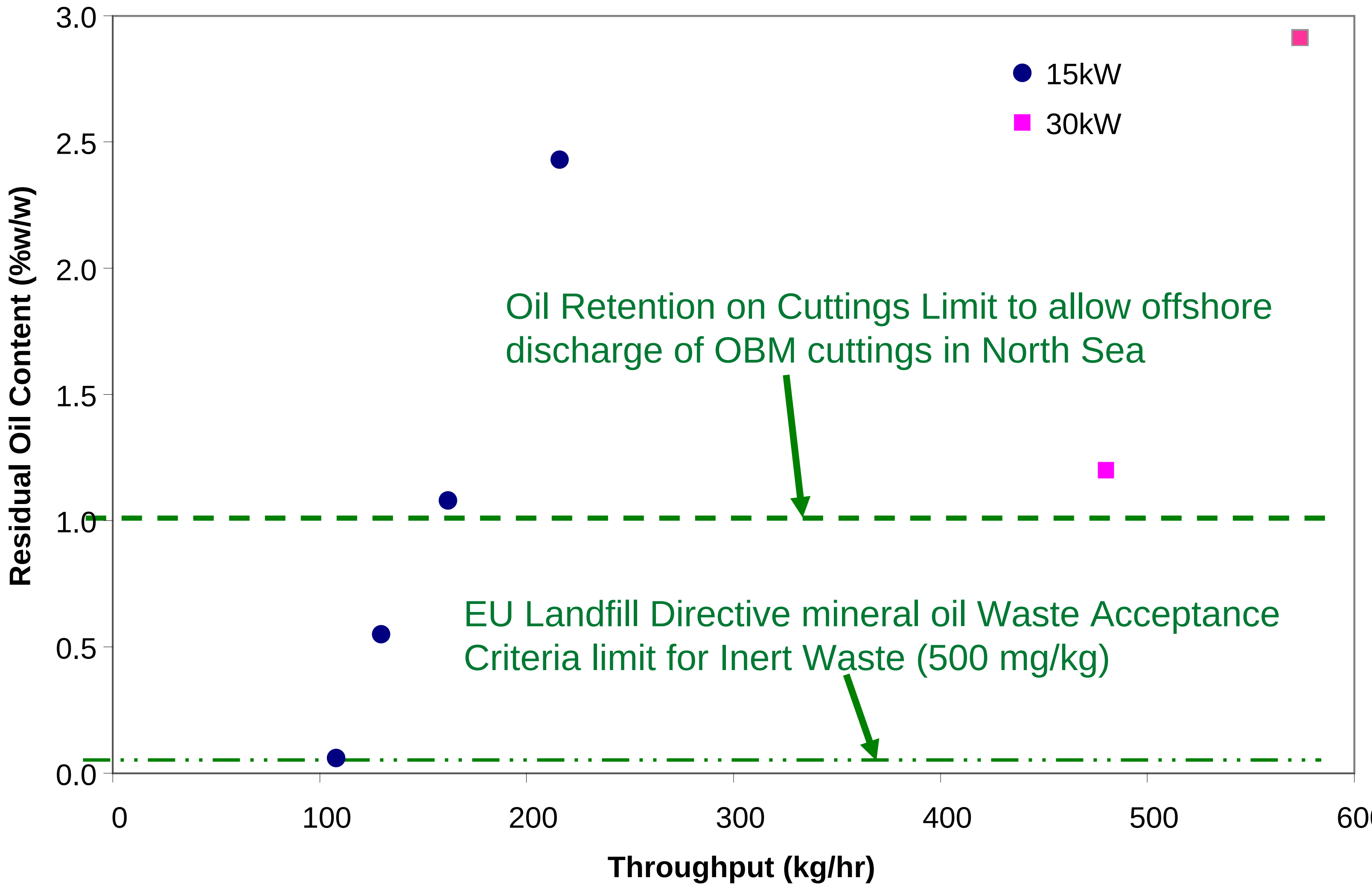


Schematic of the pilot scale continuous treatment apparatus



Fully Operational 500kg/hr Microwave Drill Cuttings Treatment Process at Nottingham University

Effect of Material Throughput



…data-set to be extended through the study of greater range of cuttings samples.

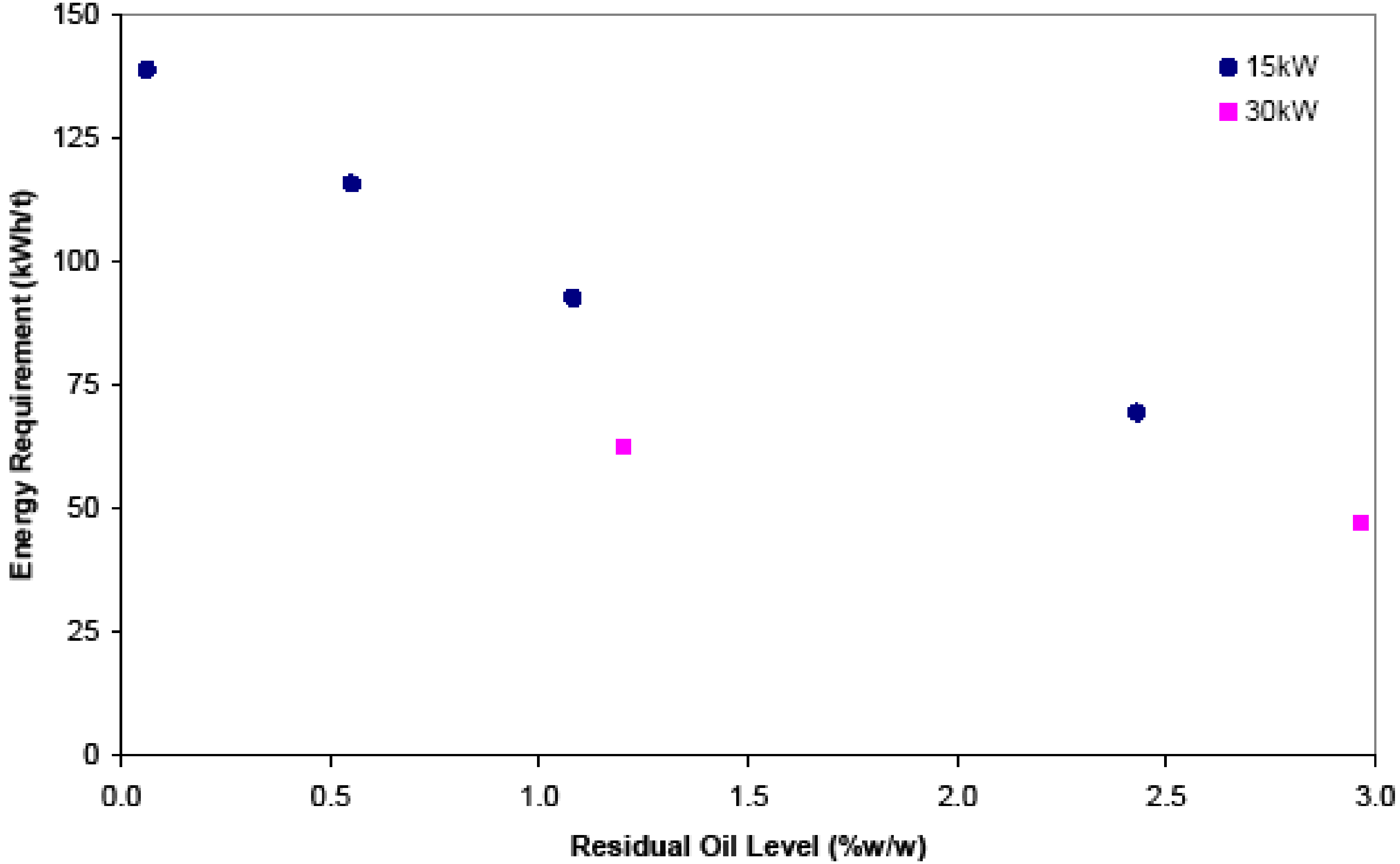
Microwave heating equation

$$Pd = 2\pi f \varepsilon_o \varepsilon'' E_o^2$$

Where

- Pd is power density (W/m^3)
- F is the frequency of the applied wave (Hz)
- ε_0 is the permittivity of free space (8.854×10^{-12} F/m)
- ε'' is the dielectric loss factor of the material being heated
- E_o is the magnitude of the electric field within the material (V/m)

Energy Requirements



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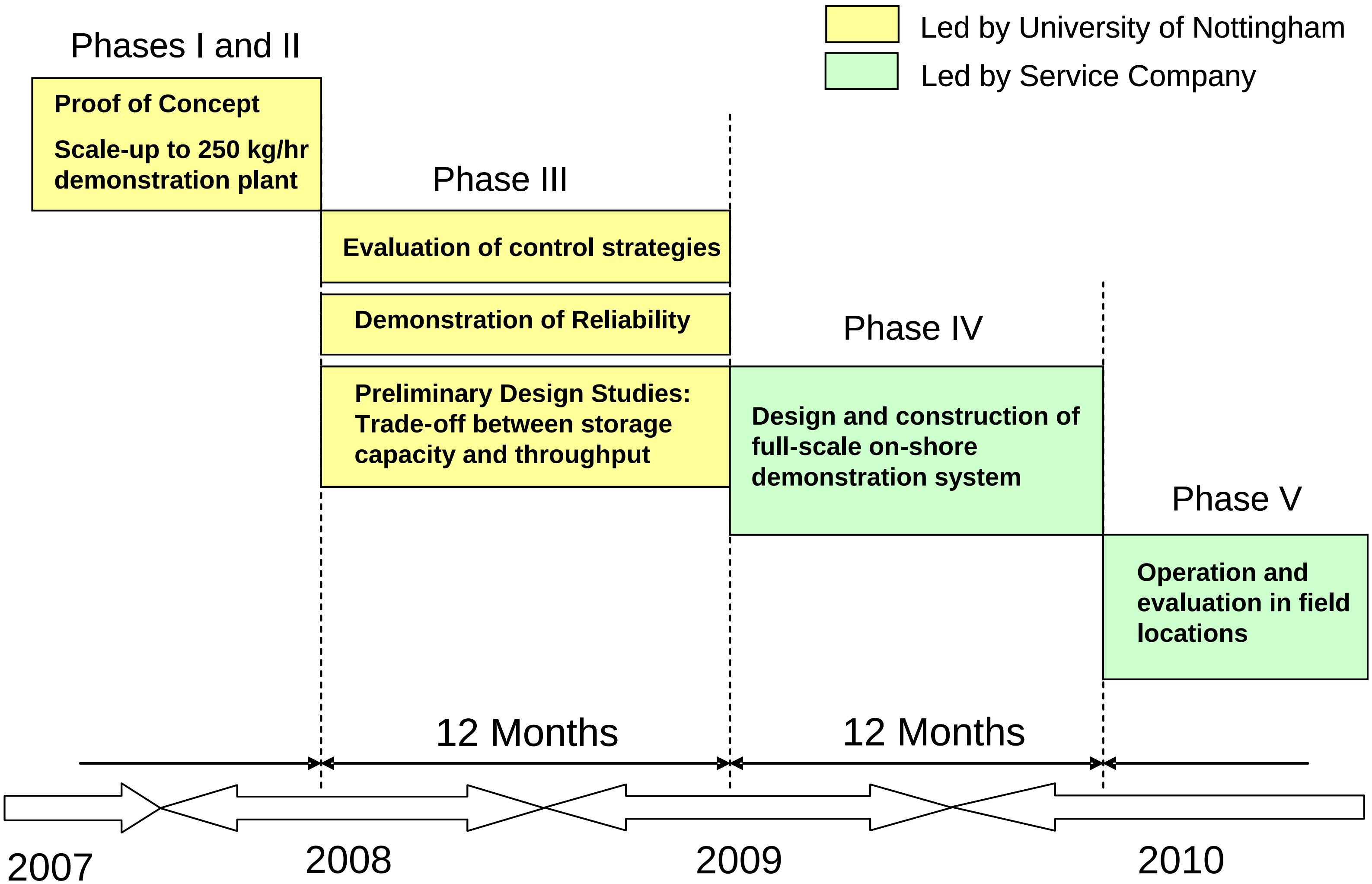
Energy Requirements

Power requirements

- Hammer mill 175 – 200 kW per 1 TPH
- PERA Microwave process 120-150kW per 1 TPH
- Nottingham Univ. Microwave process 70 - 80 kW per 1 TPH

Microwave Treatment of Oil Contaminated Drill Cuttings – Project Roadmap



Advantages / USPs

- Simple process - unique heating and oil removal mechanisms
- Low residence time / fast processing rates
- Can achieve < 1% **AND** <0.1 % oil retention (hence, offshore and onshore applications)
- Small footprint
- Low power requirements 70 - 80 kW per 1 TPH cuttings
- Low equipment capex and opex compared to existing indirect thermal desorption systems
- Inherently safer system for use offshore

Opportunities

- Low capex and small footprint provides much wider applicability and economic viability than currently exists for thermal desorption technologies.
- Opportunity to improve offshore drilling performance by using oil based muds instead of water based muds in top hole sections due to the small footprint / high throughput capability of the process.

The future

- Offshore processing is the key.
- Alternative technologies – microwave
- Inter-field transfer / offsite offshore CRI disposal
- Improved water handling systems
- Industry has travelled a long way. It’s offshore impacts are now negligible compared to where it was in the 70’s / 80’s.

Thank You !